

# High-Pressure Geoscience at GSECARS

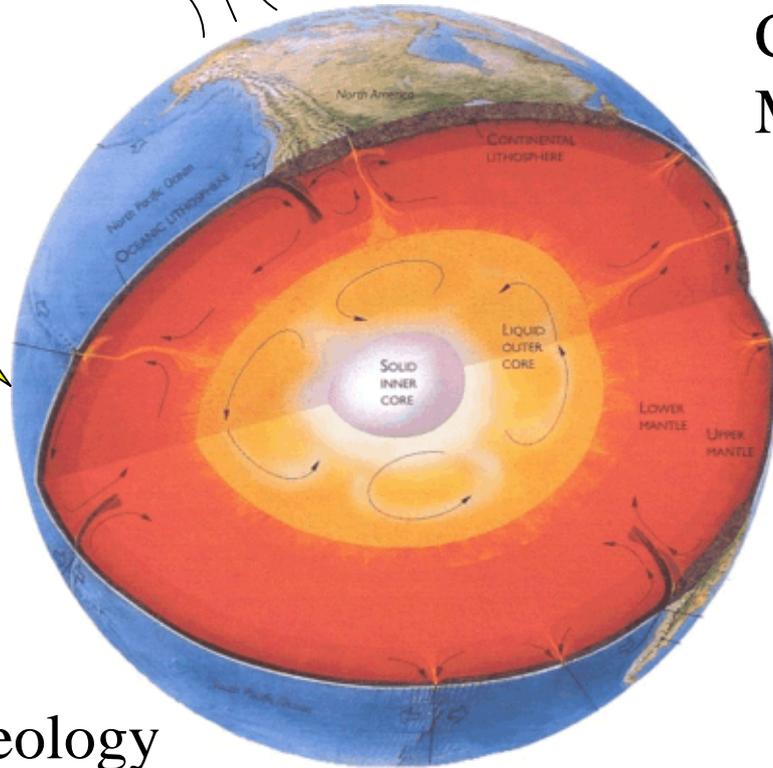
Guoyin Shen

- Geoscience and micro beams
- Micro beams at GSECARS
- Science highlights

Geomagnetism

Astronomy  
Cosmochemistry  
Meteoritics

Seismology



Field geology

Tectonics

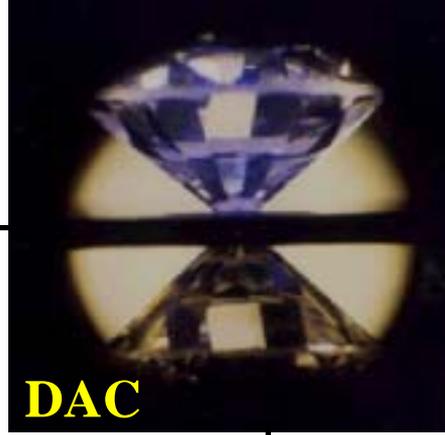
High pressure experiments

...

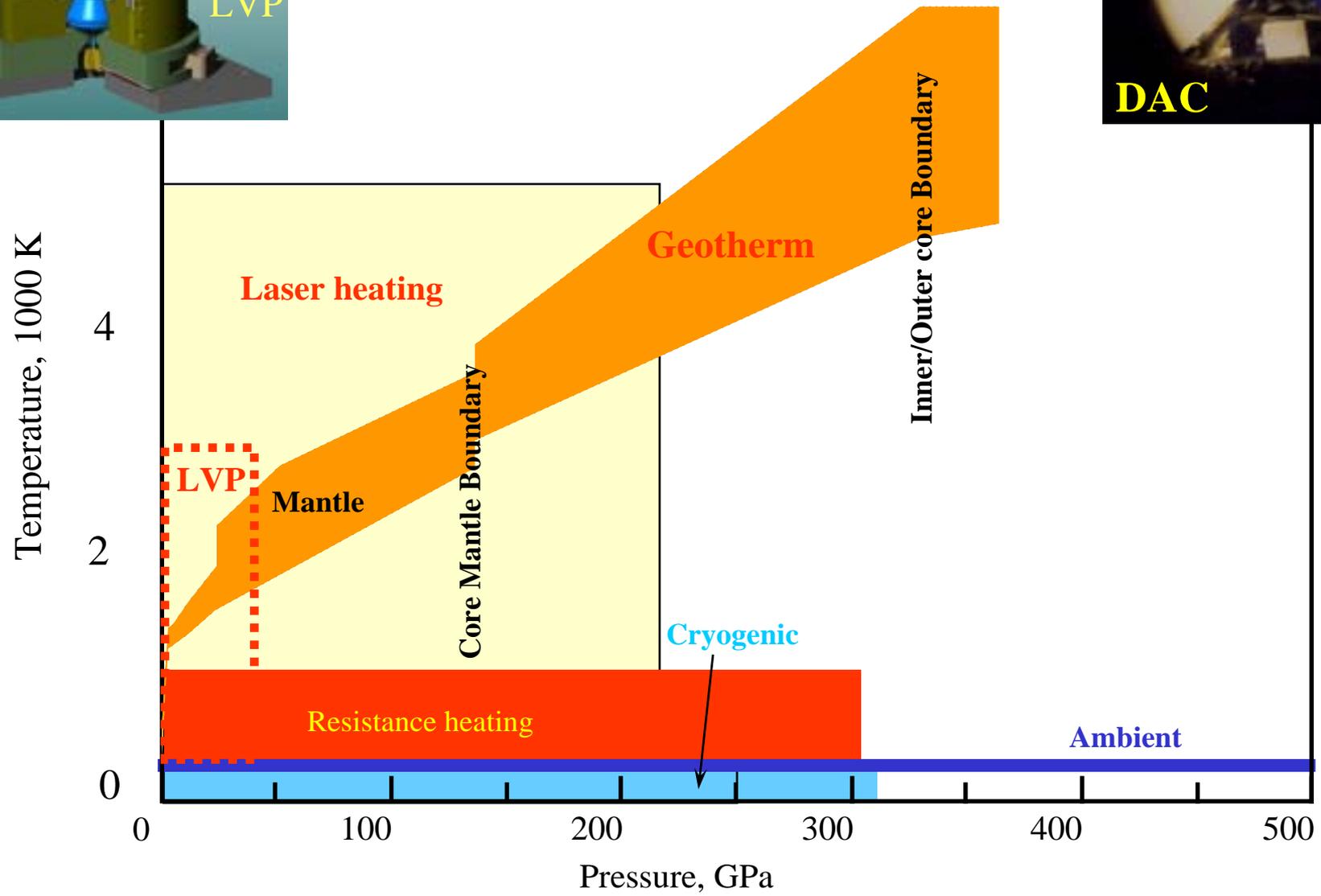
A geotherm together with accessible  $P$ - $T$  ranges by static techniques



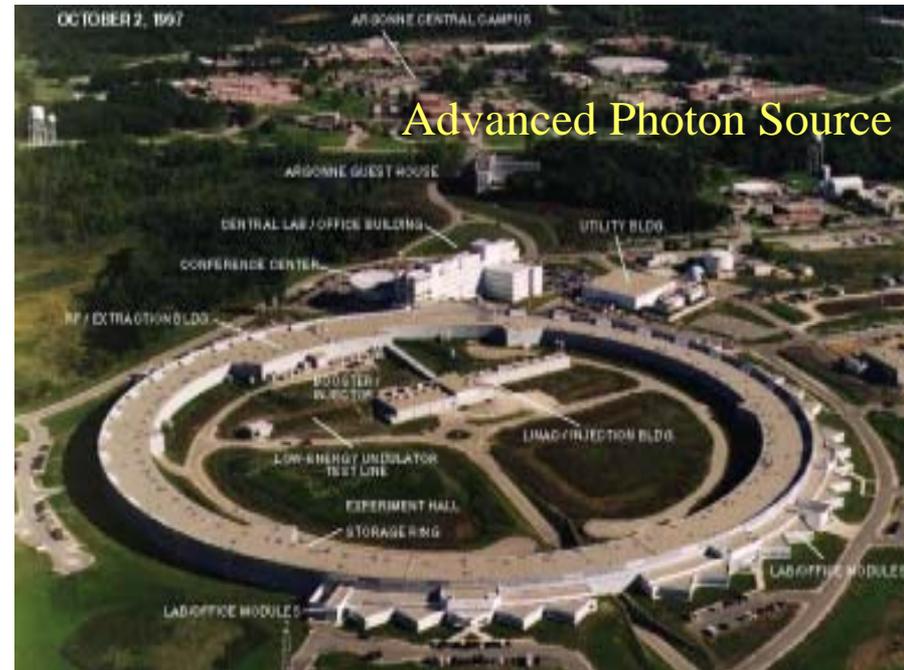
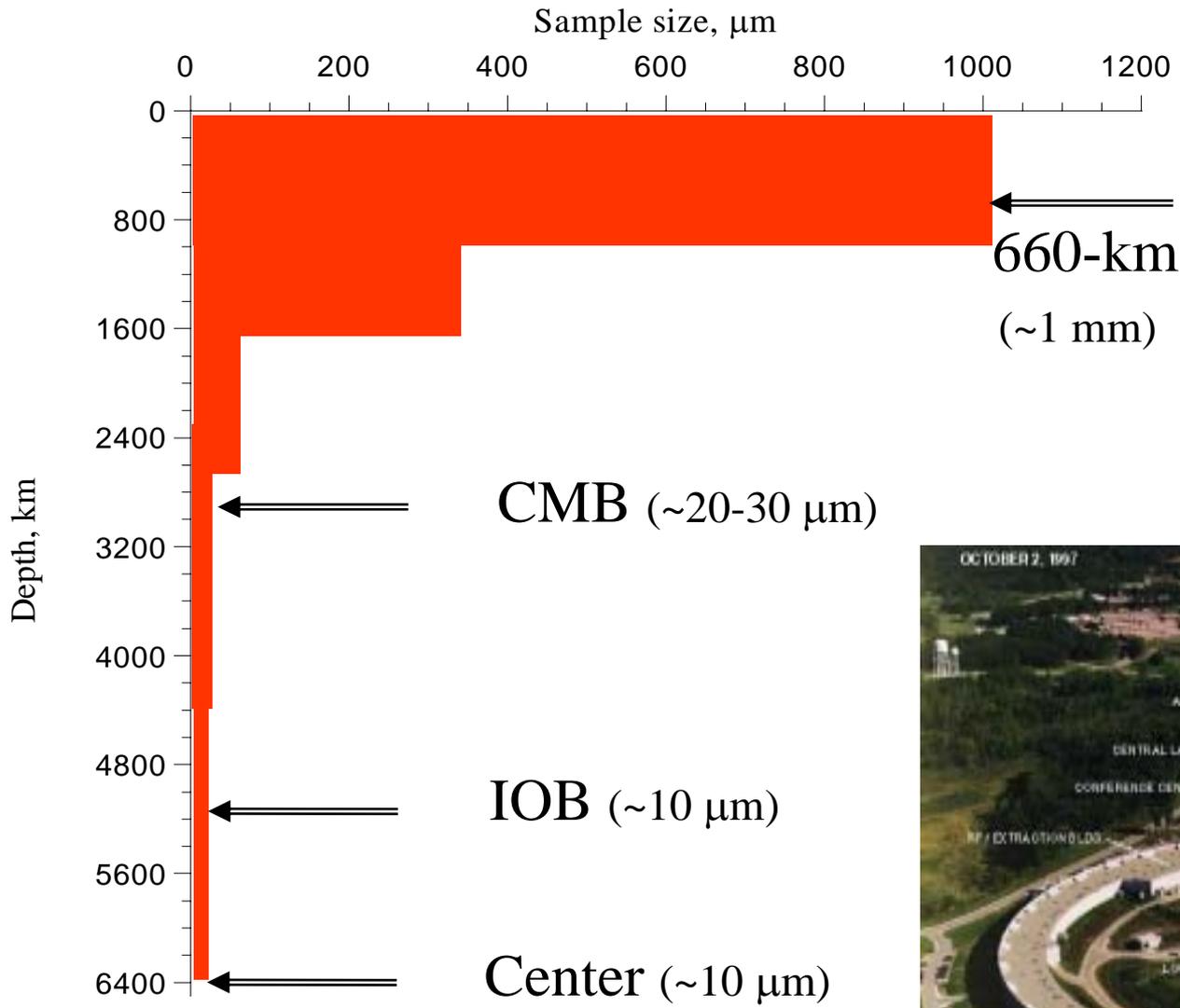
LVP

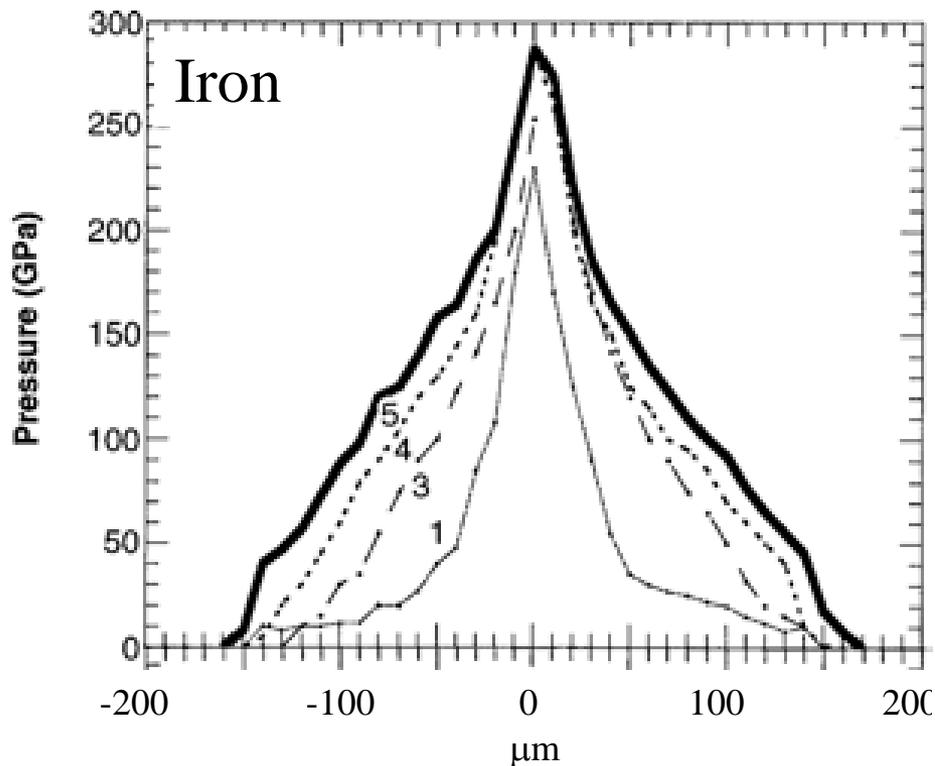


DAC

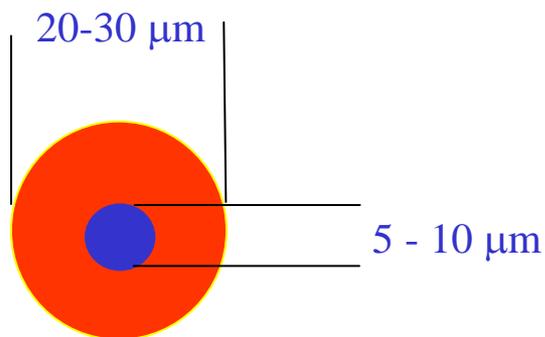


# High $P$ - $T$ conditions are achieved at the cost of reducing sample volume

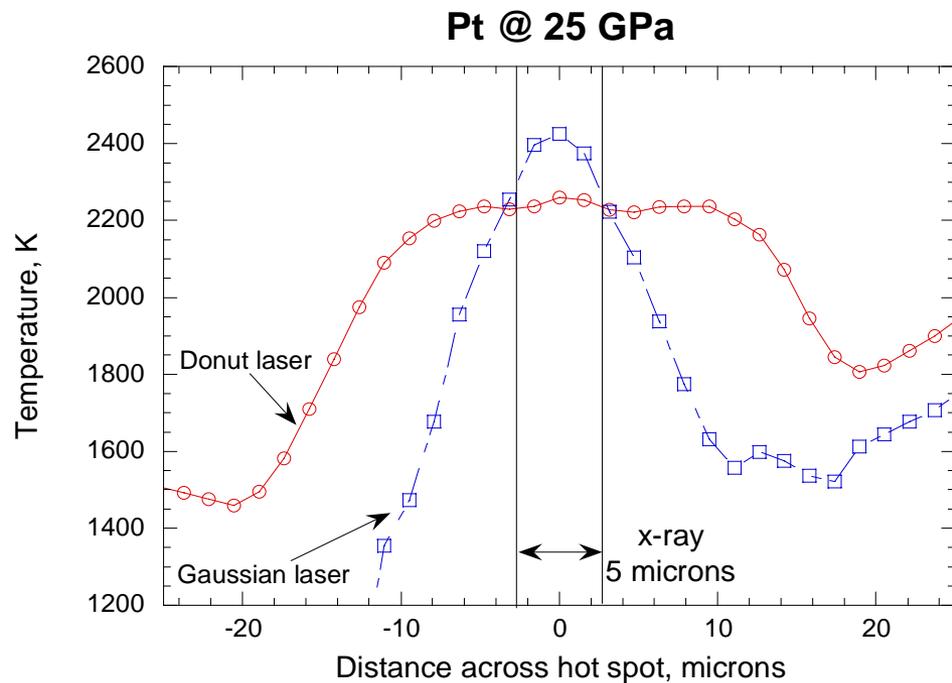




Pressure distributions across a sample chamber in a DAC



Temperature profiles of laser heating spots in a DAC



# Micro beams at GSECARS



$\varnothing 5-10 \mu\text{m}$

Table top slits

Clean up slits

100-200 mm long K-B

1-m long K-B mirrors

$\varnothing 25-70 \mu\text{m}$

Clean up slits

1-m long K-B mirrors

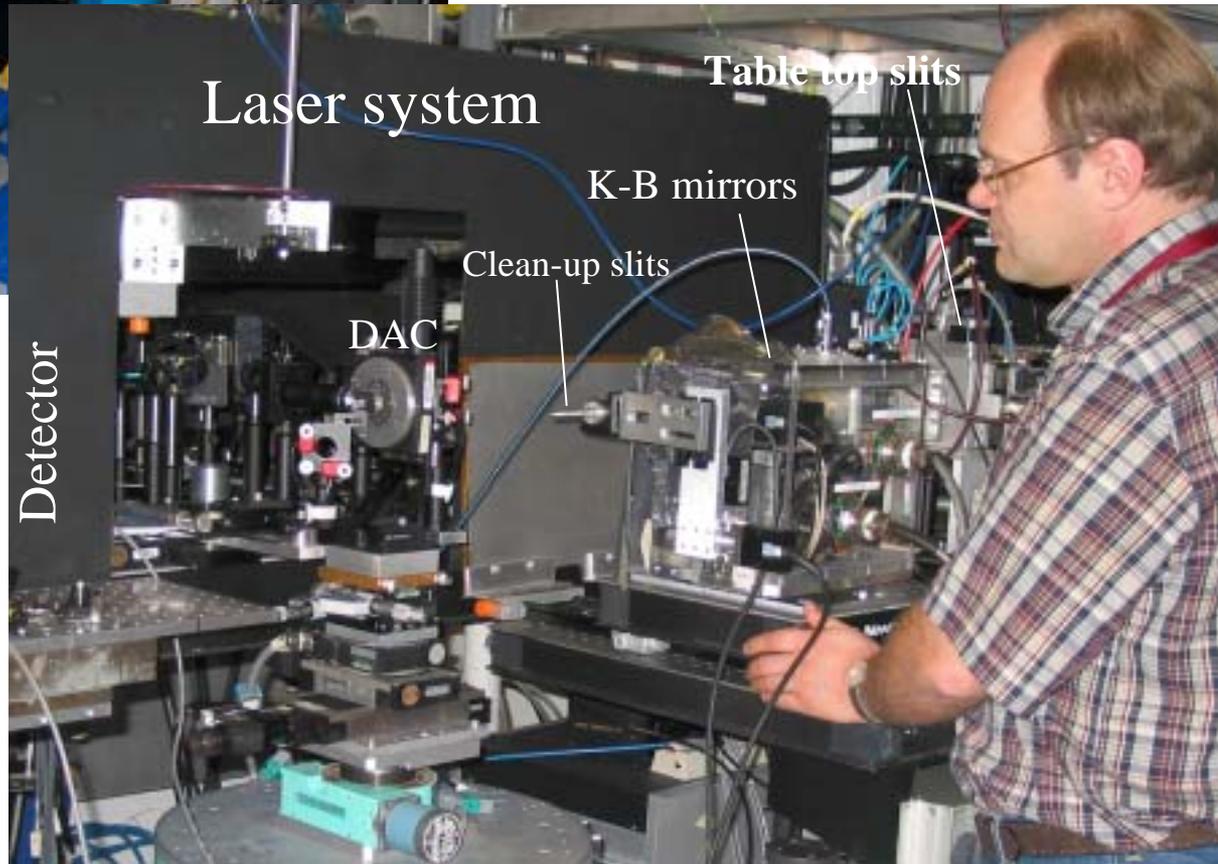


Beam size: 5-10  $\mu\text{m}$   
DAC setup at the 13 ID-D



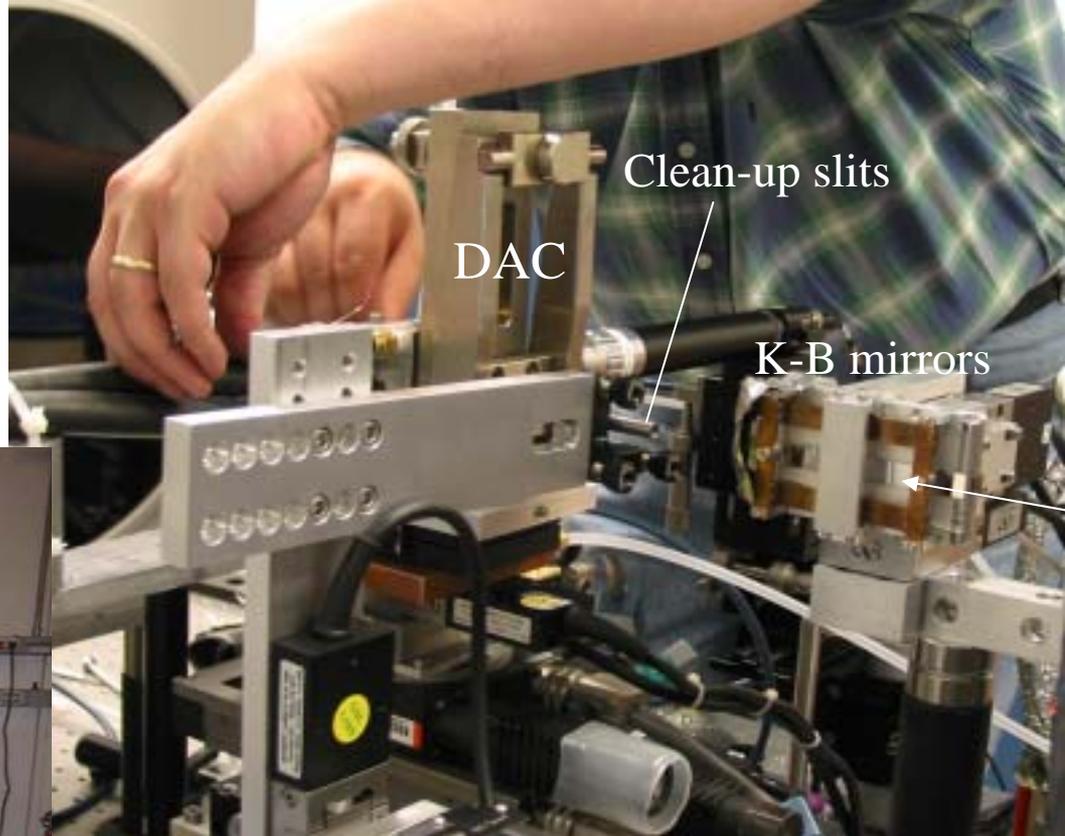
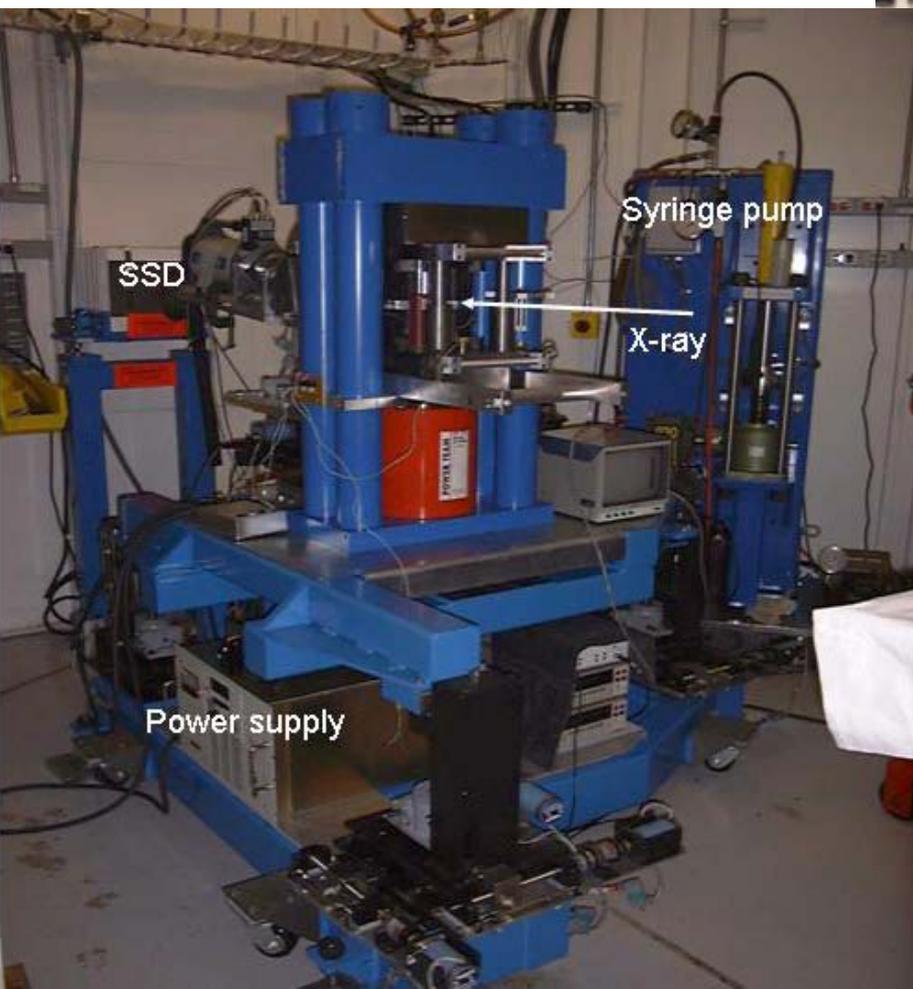
LVP setup at the 13ID-D

Beam size: 50-150  $\mu\text{m}$



Beam size: 50-200  $\mu\text{m}$

LVP setup at the 13BM-D



DAC setup at the 13 BM-D

Beam size: 5-50  $\mu\text{m}$

# Beam size selection

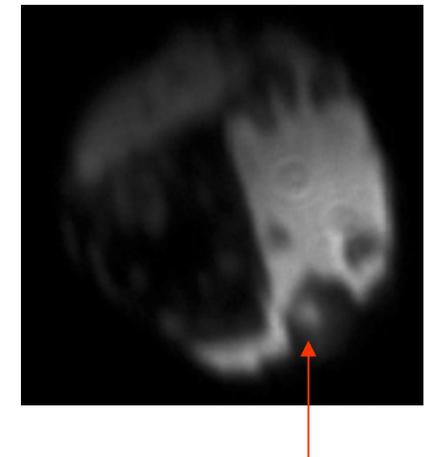
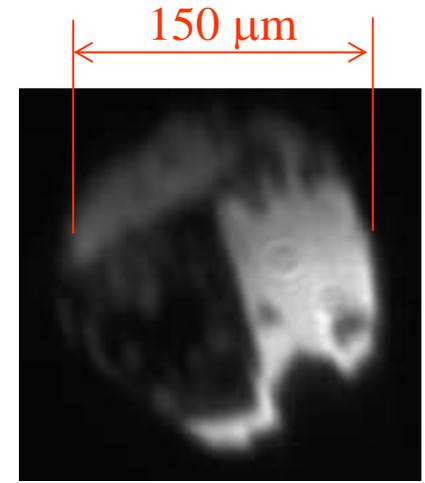
- Spatial resolution → smaller beam size
  - P-T gradients, multiple samples, ...
- Statistics → larger beam size
  - grain size

LVP:

- Sample chamber size: 500 – 2000  $\mu\text{m}$
- Beam size: 50 – 200  $\mu\text{m}$

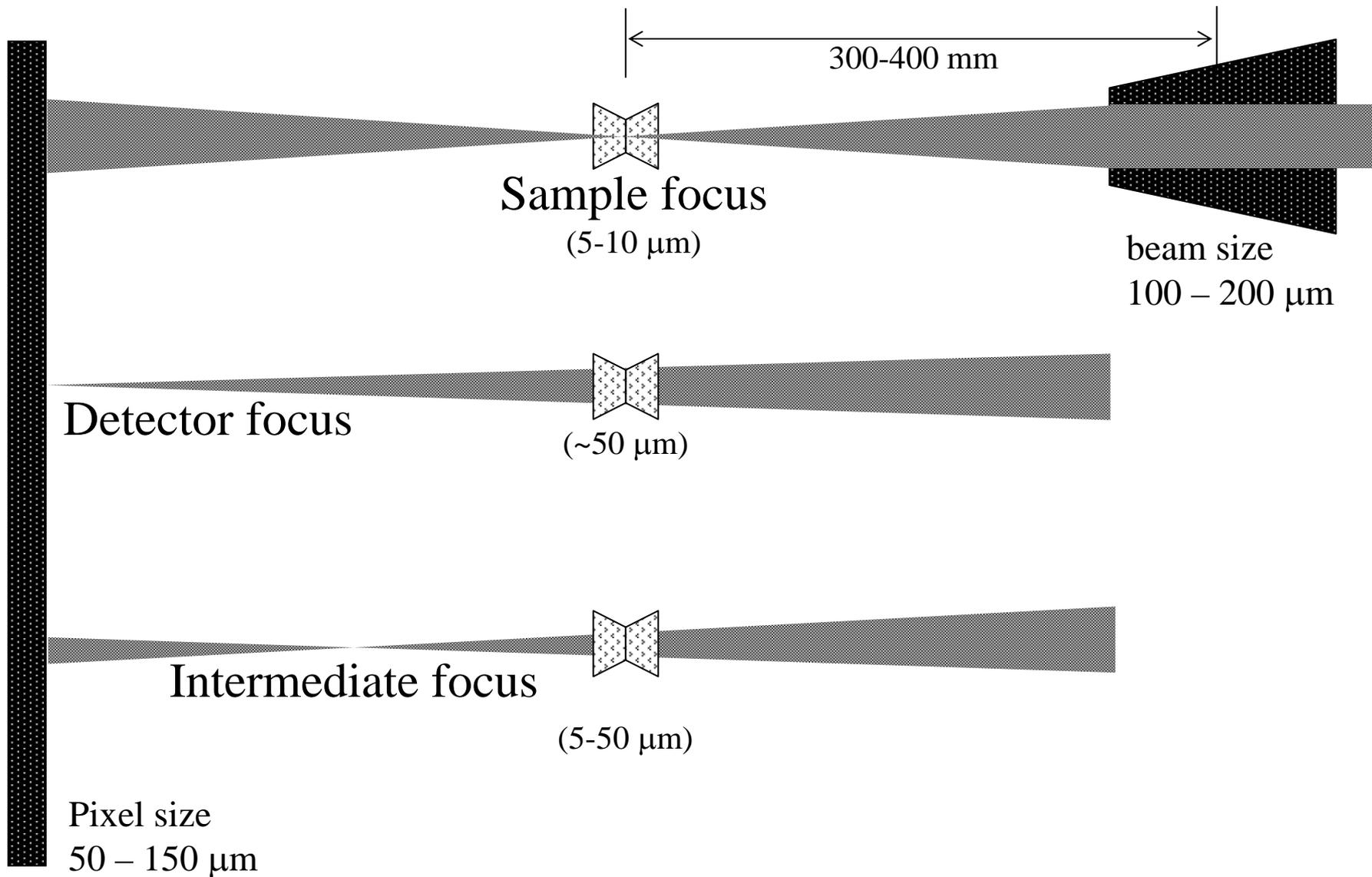
DAC:

- Sample chamber size: 30 – 1000  $\mu\text{m}$
- Beam size: 5 – 50  $\mu\text{m}$

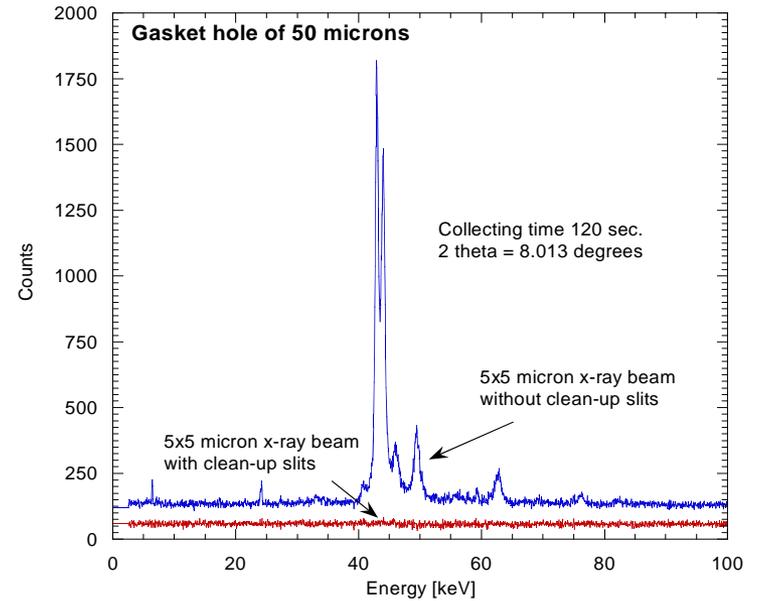
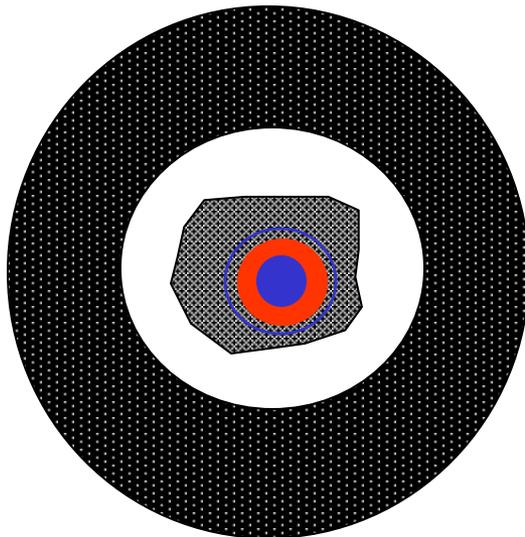
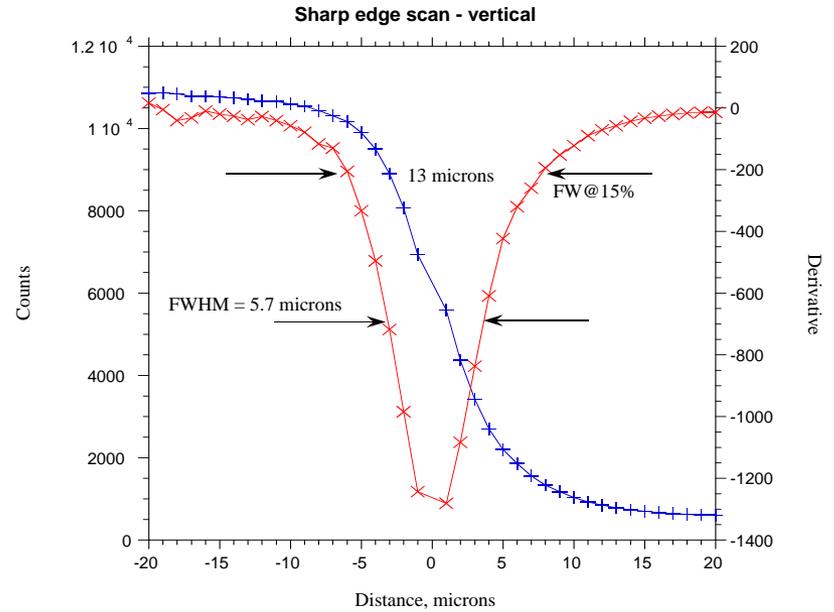
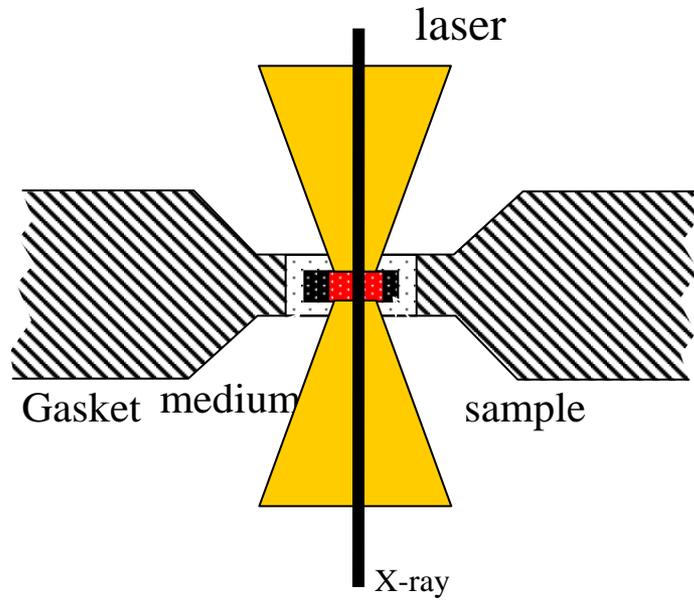


X-ray  
(5-7  $\mu\text{m}$ )

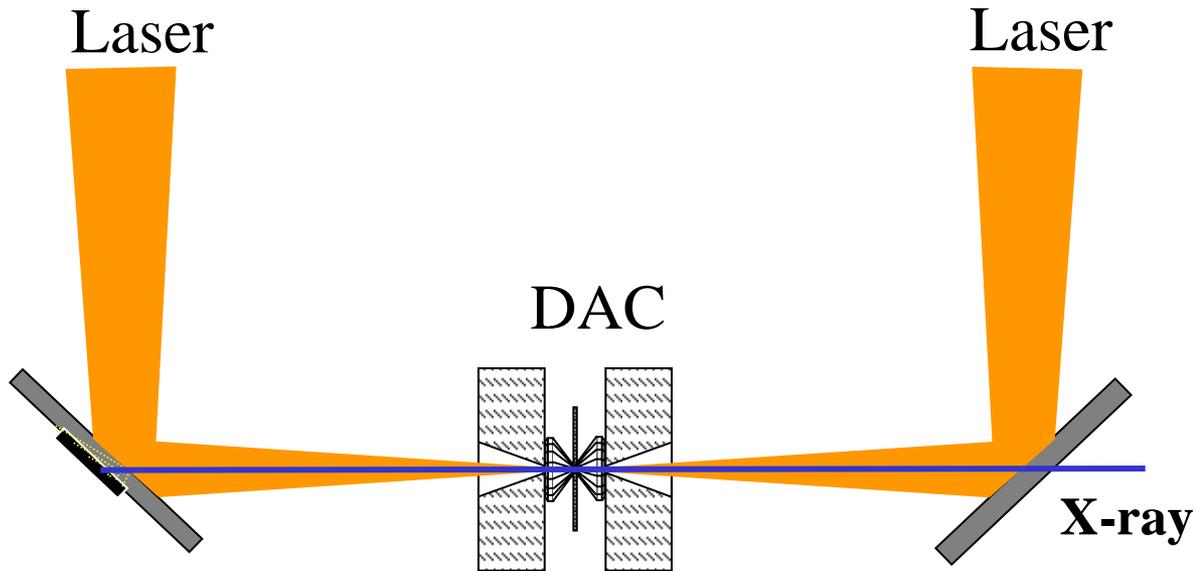
# Beam size and diffraction resolution



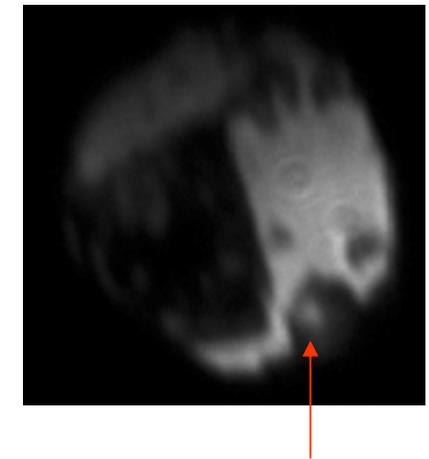
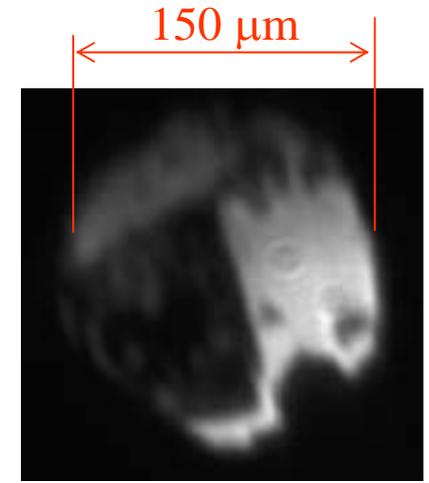
# Beam cleanliness



# X-ray beam visibility



**Visible image of x-ray ensures the alignment with laser heating spots.**



X-ray  
(5-7  $\mu\text{m}$ )

# Science Highlights

**1. Liquid iron at high pressures**

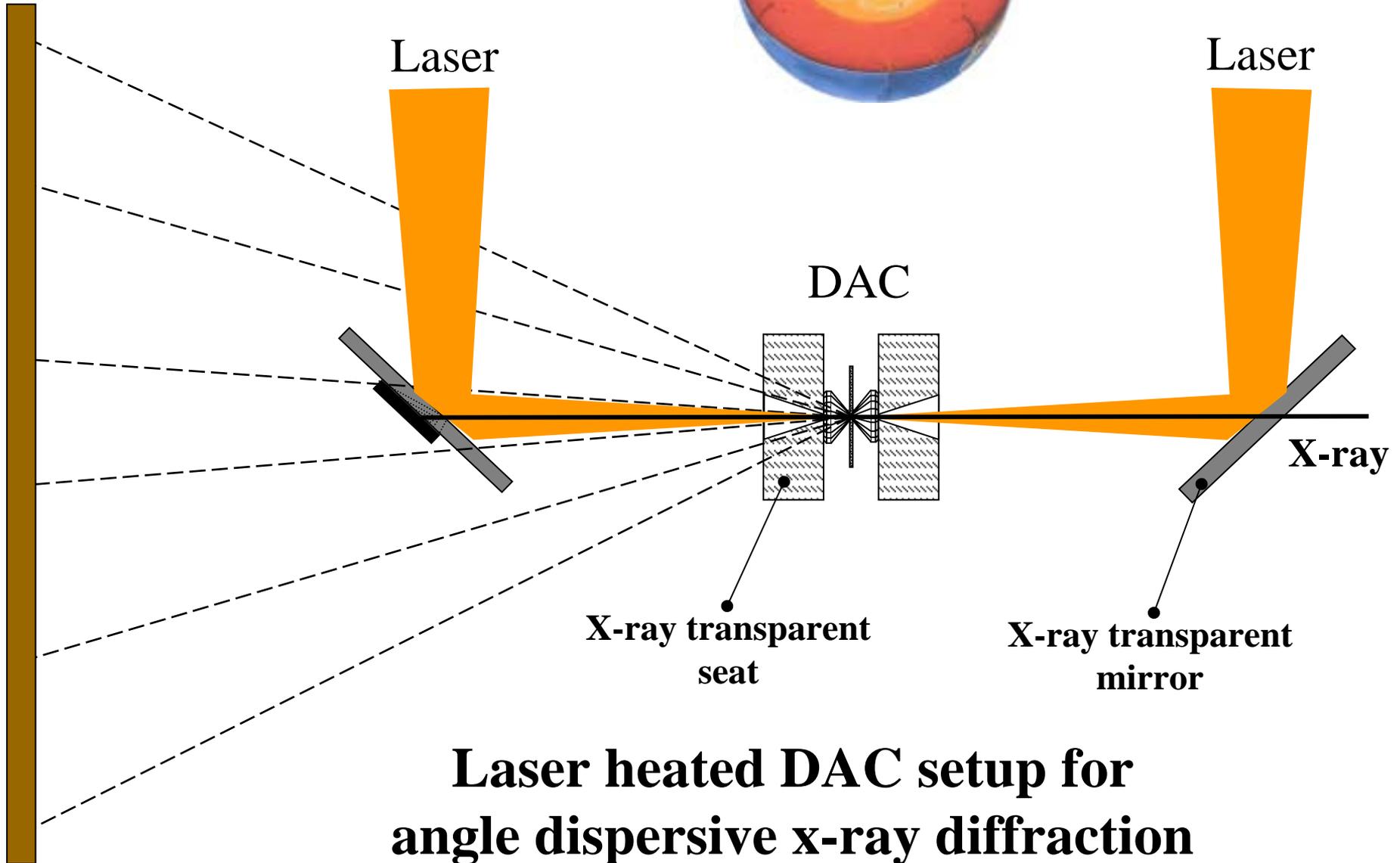
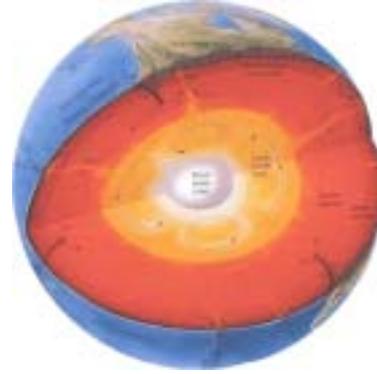
**2. Density of liquids**

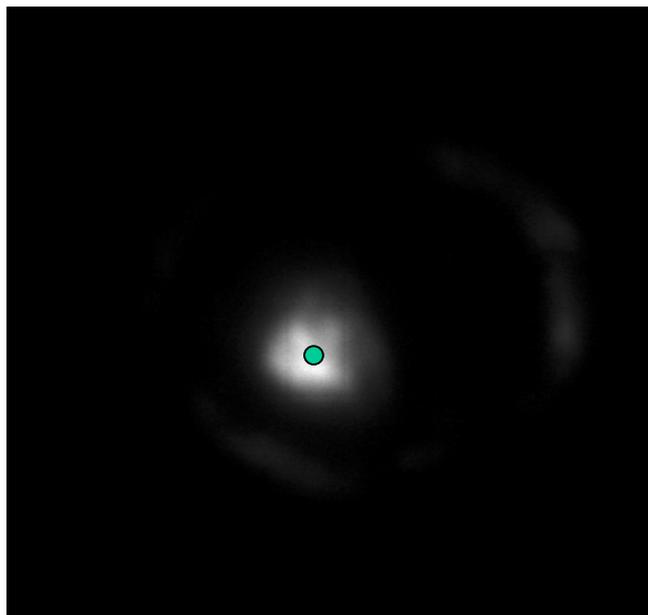
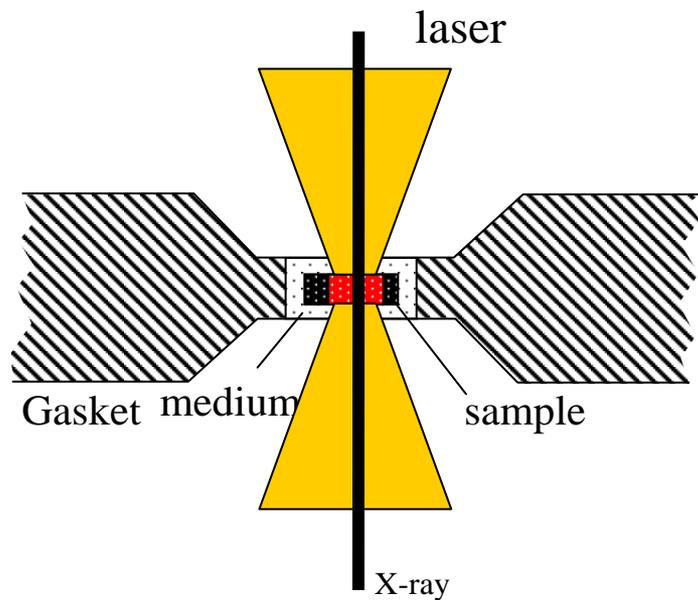
**3. Phase stability at P-T conditions inside Earth**

**4. Spin state of iron in FeO at Mbar pressures**

# Liquid iron at high pressures

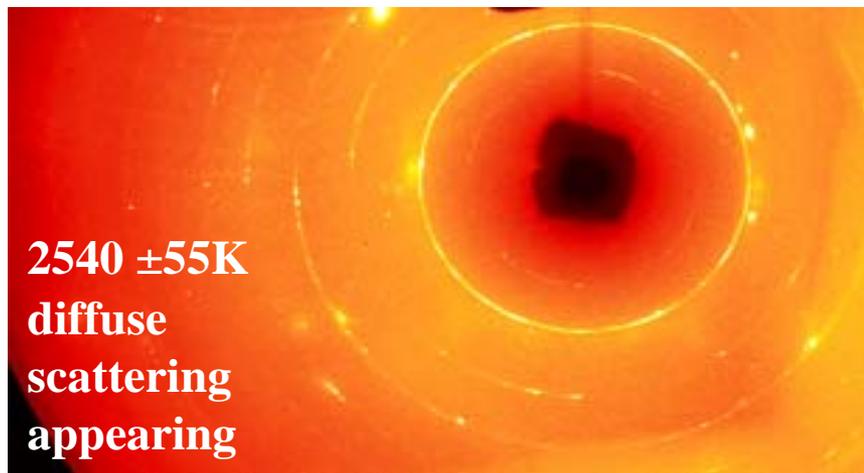
- \* the outer core is liquid
- \* the inner core is solid
- \* the main composition of the core is iron



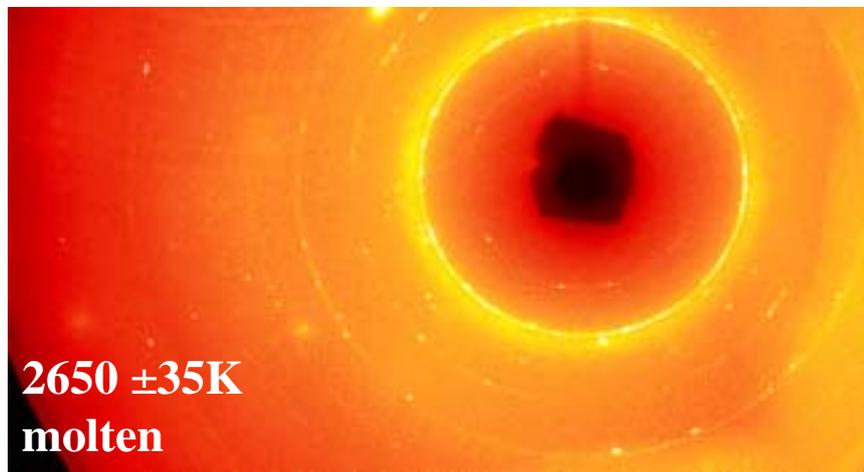


**Fe at 50 GPa**

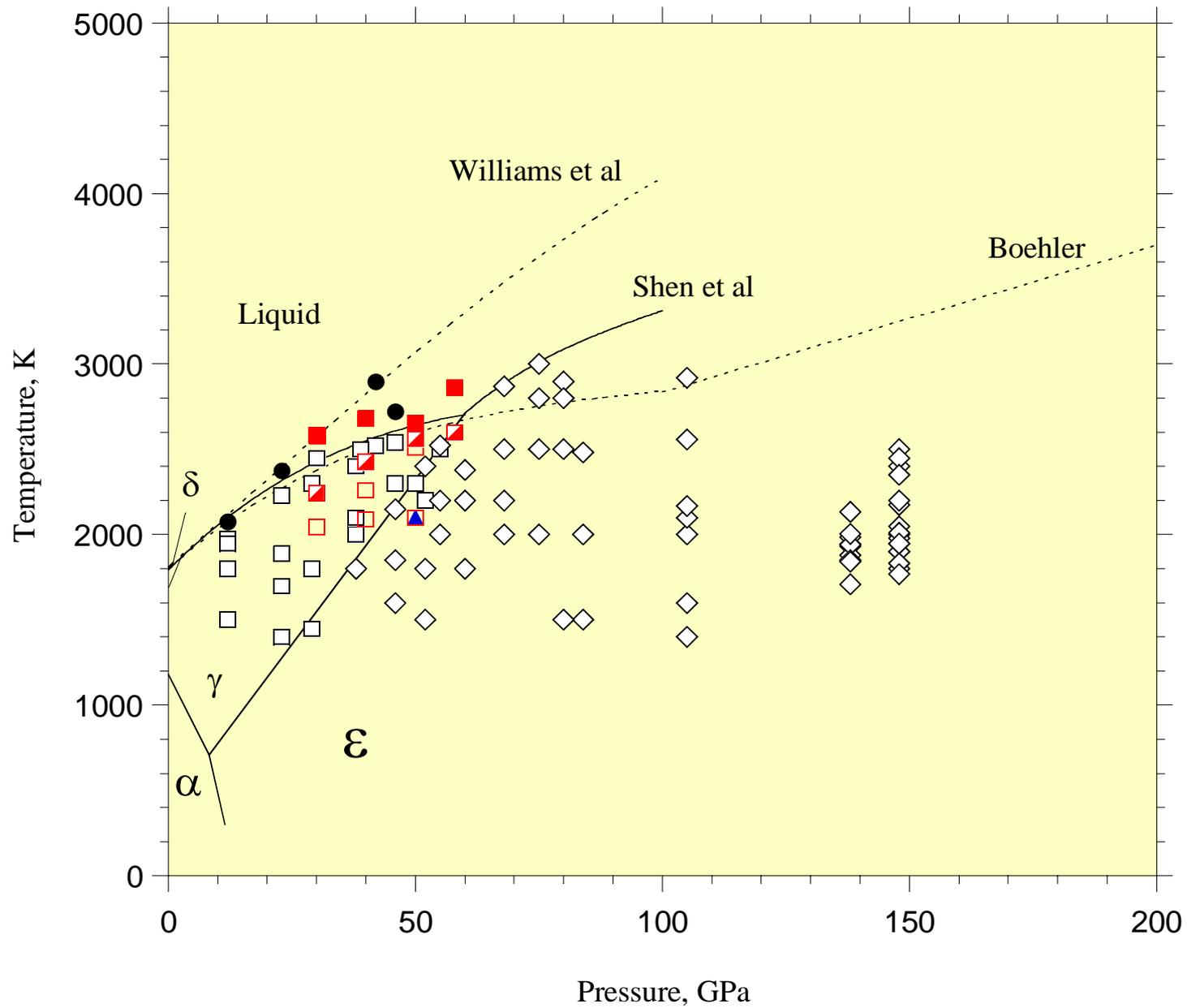
**2420  $\pm$ 40K  
crystalline**



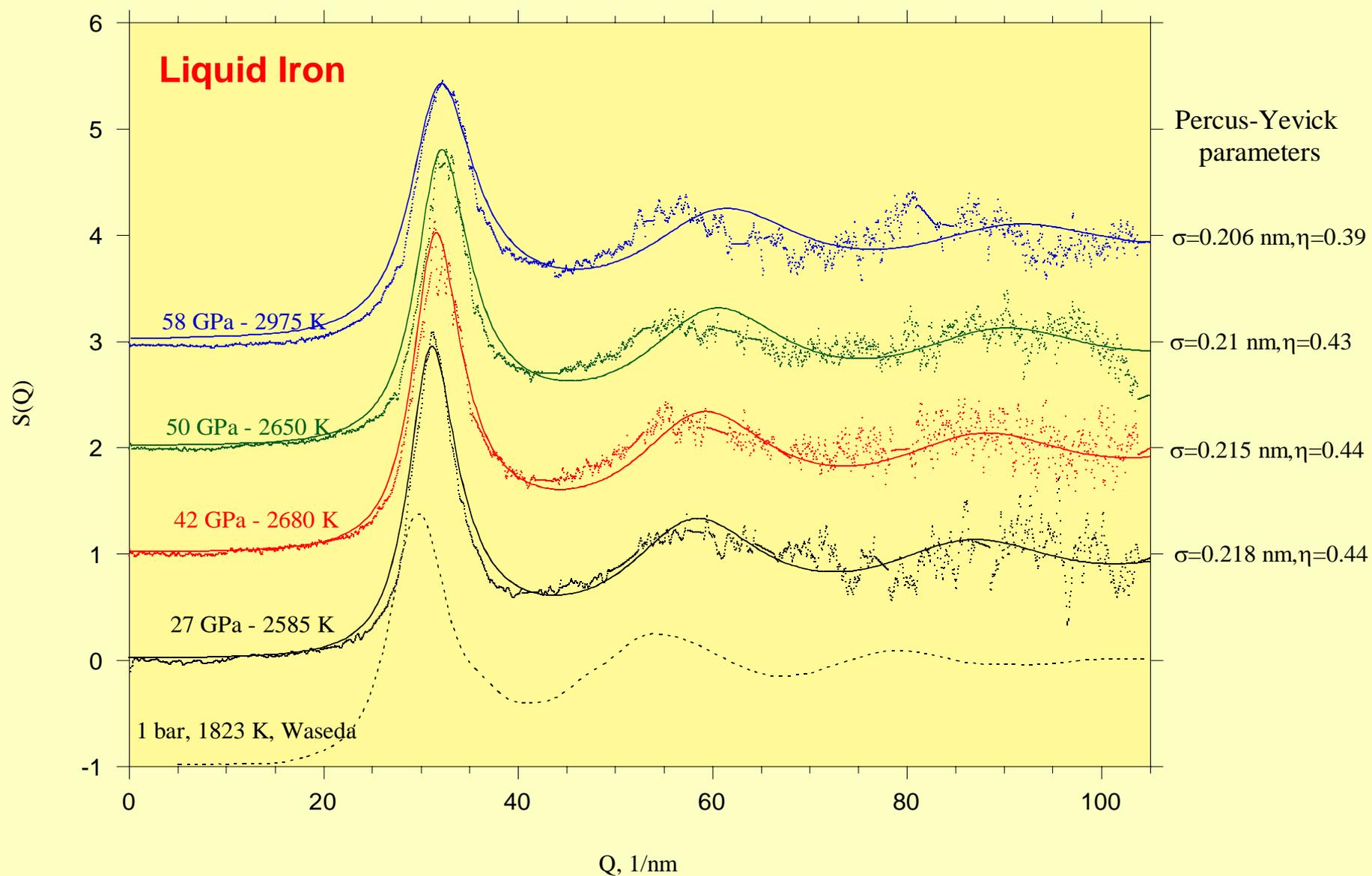
**2540  $\pm$ 55K  
diffuse  
scattering  
appearing**



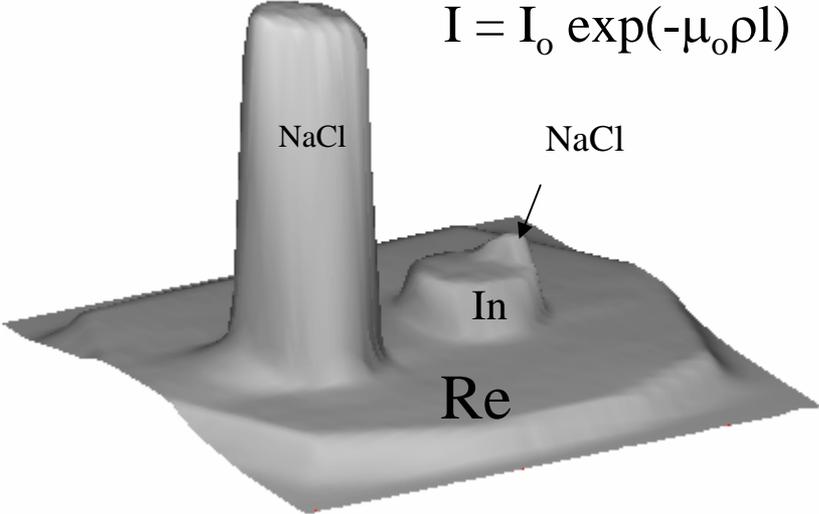
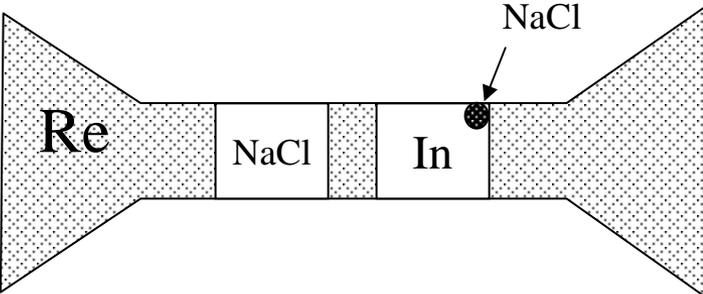
**2650  $\pm$ 35K  
molten**



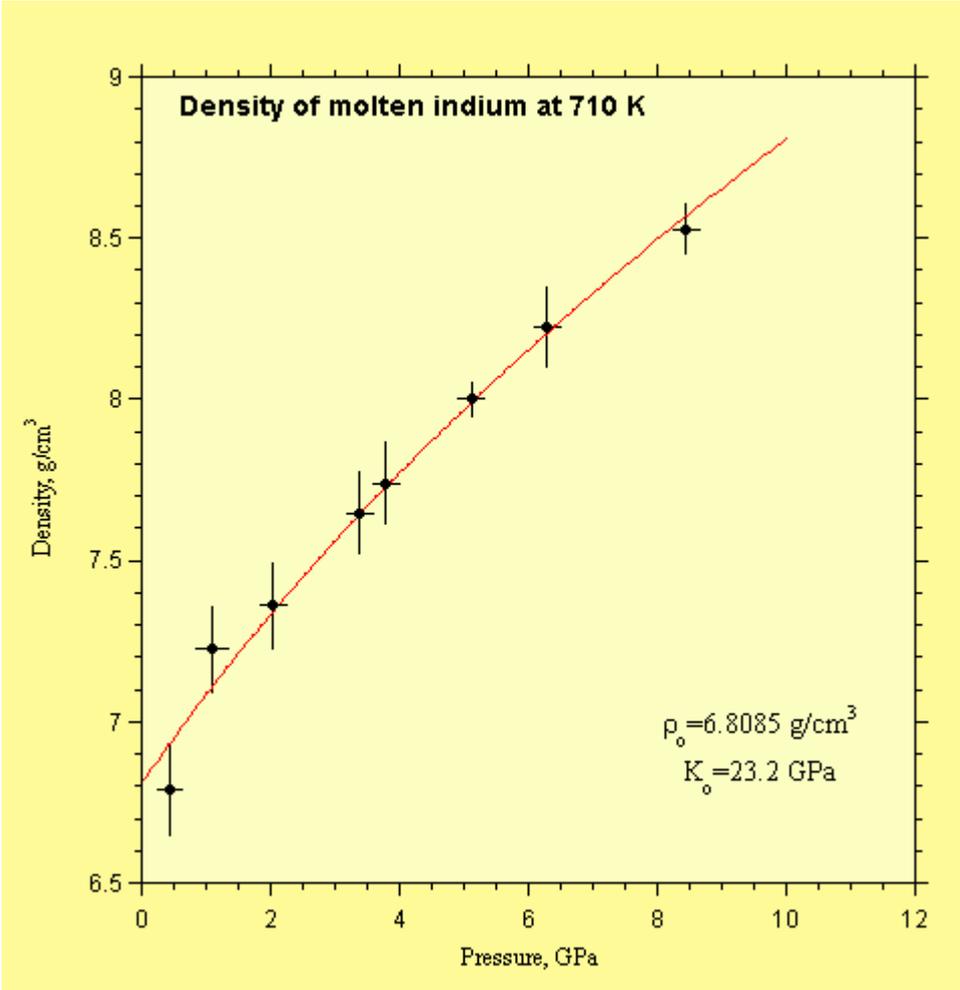
# Structure factors of liquid iron along the melting curve



# Density of liquid indium

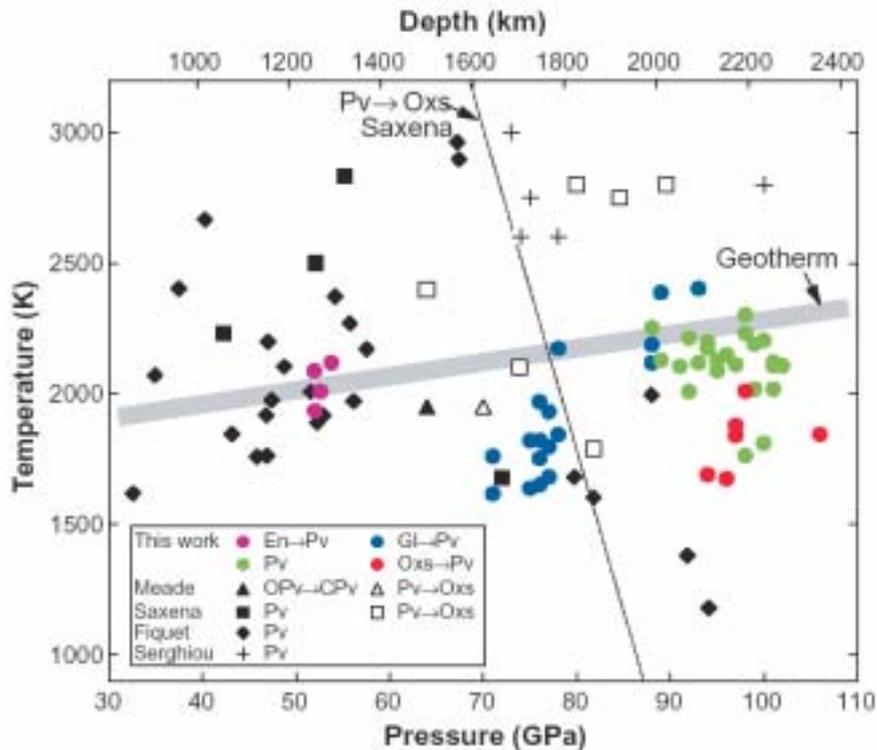


2D scan with 5x5 μm beam



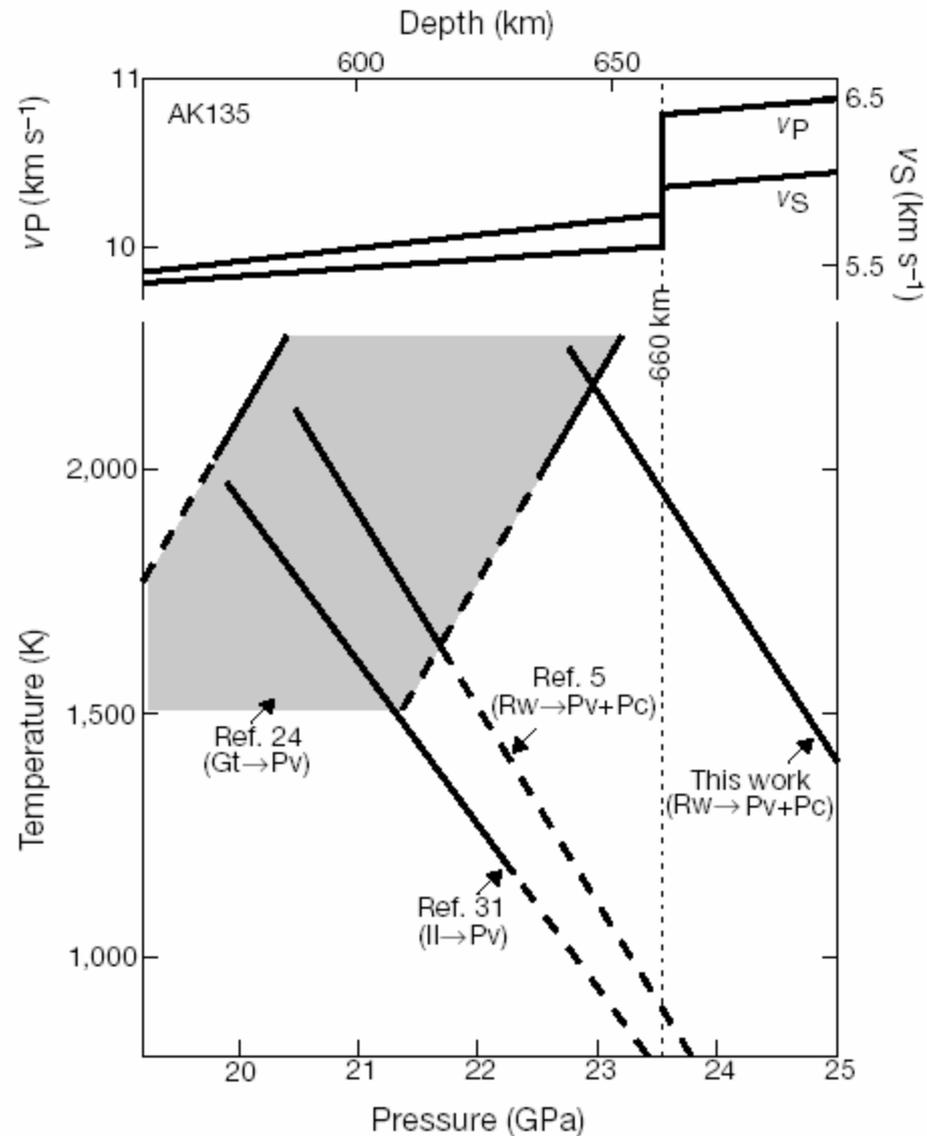
=> P-V-T equations of state for liquids

# Mantle mineralogy



**MgSiO<sub>3</sub> perovskite is found to be stable to at least 2300 km depth**

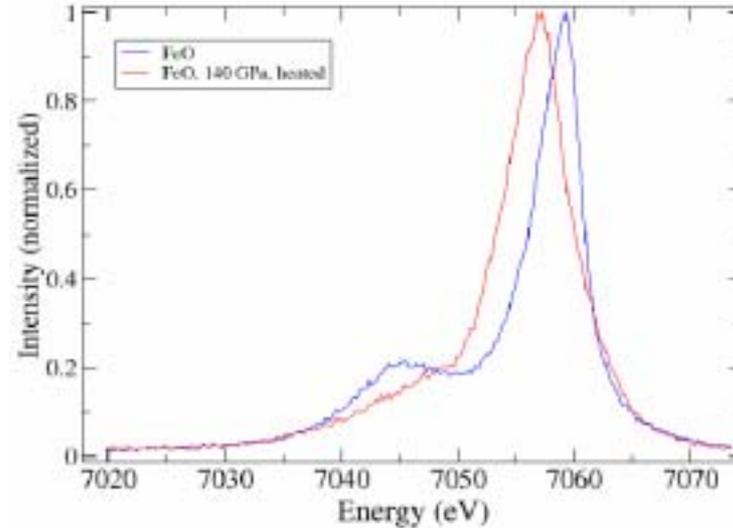
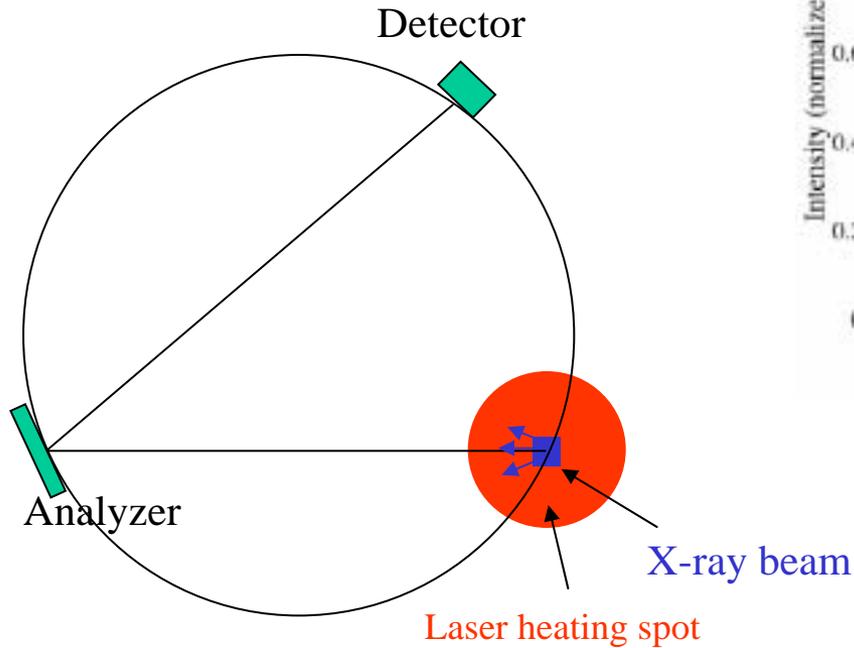
Shim, Duffy, Shen, Science (2001)



**The post-spinel transformation in Mg<sub>2</sub>SiO<sub>4</sub> is consistent with the 660-km discontinuity.**

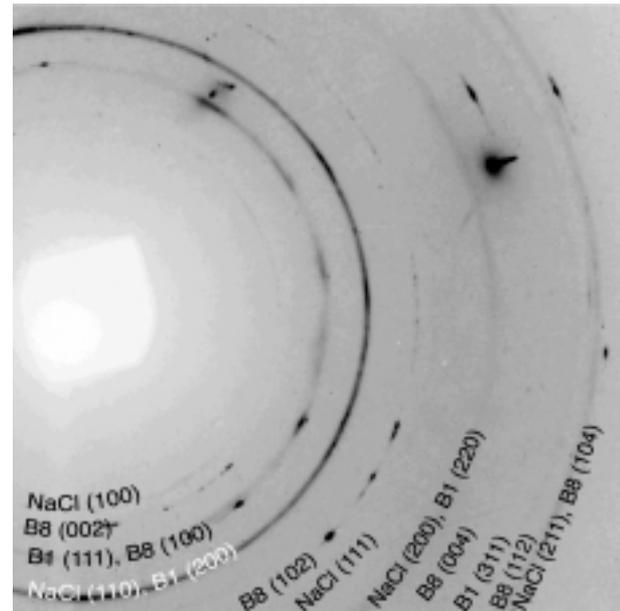
Shim, Duffy, Shen, Nature (2001)

# Integrated studies of x-ray diffraction and emission spectroscopy



High-resolution  $\text{Fe K}_\beta$  x-ray emission spectra of  $\text{Fe}_{0.947}\text{O}$  at 140 GPa.

Badro et al PRL(2000)



A CCD diffraction image from  $\text{Fe}_{0.92}\text{O}$  at 136(5) GPa and 1500(100) K. Six new lines, assigned to the normal B8 phase of FeO, appear at this pressure in an isothermal compression at 1500 K.

Sata et al submitted

**Micro beam plays an important role in high pressure experiments with precision and accuracy that rivals those at ambient conditions.**

# Acknowledgement

## **GSECARS staff**

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